MOVEMENTS BY SMALL MAMMALS ON A RADIOACTIVE WASTE DISPOSAL AREA IN SOUTHEASTERN IDAHO

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ABSTRACT.—Average linear movement by populations of *Dipodomys ordii*, *Microtus montanus*, *Perognathus parvus*, and *Peromyscus maniculatus* was investigated over a 15-month period by live trapping on a low-level, radioactive waste disposal area in Idaho. No significant differences in movement among habitats were observed seasonally, excepting *M. montanus* in spring. Average linear movements within habitats ranged from 20 to 70 m for all species, but some patterns varied seasonally and among age classes for individual species. Although predation on contaminated small mammals from the disposal area is a vector of radionuclide transport, local movements by these rodents do not appear to be of sufficient magnitude to contribute significantly to redistribution of radioactive particles.

The measurement of movements by small mammals has received considerable attention in ecological studies dealing with life history and estimation of density (Sanderson 1966). Recently several studies have focused on contamination of small mammals with chemical residues or radionuclides (e.g., Jefferies et al. 1973, Halford and Markham 1978), but only one investigation has considered movements by small mammals in the vicinity of a contaminated area (Hedlund and Rogers 1980). Preliminary studies on a radioactive waste disposal area in southeastern Idaho indicated that deer mice (*Peromyscus maniculatus*) tissues collected adjacent to the disposal area had higher concentrations of some radionuclides than tissues from control areas (Markham 1978, Markham et al. 1978). These data suggested that small mammals had access to contaminated soil areas near waste or were in direct contact with waste. Thus, small mammals could affect radionuclide distribution during their burrowing activities and move contaminated material in their gut, hide, or lungs.

On the basis of these observations, we undertook a study to examine the ecology and radioecology of small mammals inhabiting the waste disposal area. One objective of this study was to determine average linear movements by small mammals whose activity could affect the spread and redistribution of radionuclides, particularly via predation. The purpose of this paper is to report movements by small mammals on and adjacent to the disposal area and compare these movements among habitats and seasons and between sexes and age classes. Data on species diversity, biomass, population dynamics, and reproduction of small mammals on the disposal area (Groves and Keller 1983a), as well as radiation doses and radionuclide contamination to small mammals on the study area (Arthur et al. in press, 1986) have been reported previously.

METHODS

Our study was conducted at the Subsurface Disposal Area (SDA) of the Idaho National Engineering Laboratory (INEL) Radioactive Waste Management Complex. The INEL Site, a nuclear reactor testing facility under the jurisdiction of the U.S. Department of Energy, occupies 231,300 ha of sagebrush desert in southeastern Idaho. Since 1952 approximately 9.9×10^4 m^3 of radioactive wastes have been placed in pits and trenches at the SDA, a 36 ha portion of the complex used for disposal of radioactive waste. Details on the types of waste disposed at the SDA and waste disposal practices are provided in Arthur et al. (1986). Vegetation on the SDA was dominated by seeded crested wheatgrass (*Agropyron cristatum*), with Russian thistle (*Salsola kali*) growing over more recently disturbed and

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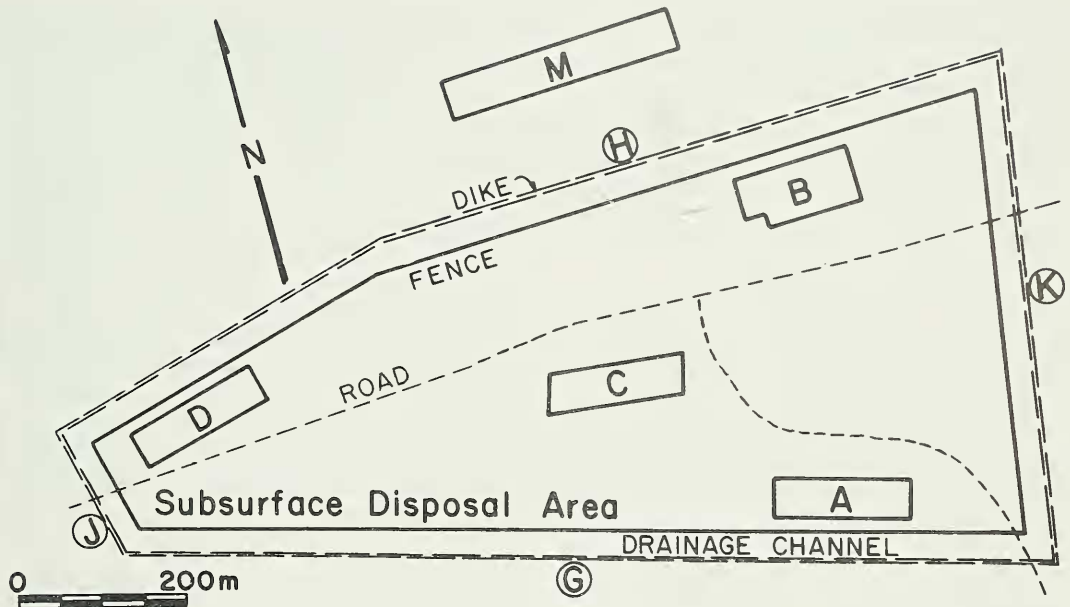
Fig. 1. Location of Grids A–D, M, and perimeter trap lines G, H, J, and K on and adjacent to the Subsurface Disposal Area.

unseeded areas. Native flora surrounding the disposal area is primarily big sagebrush (*Artemisia tridentata*)/bluebunch wheatgrass (*Agropyron spicatum*) steppe. Further details on the study area are provided in Groves and Keller (1983b).

Four trapping grids (A, B, C, D), each 0.6 ha and containing 100 Longworth live traps placed at 9 m intervals in a 5 x 20 configuration, were established on the SDA between May and July 1978 (Fig. 1). A fifth grid (M) was established in native vegetation 150 m north of the SDA during October 1978 and consisted of 160 live traps in a 5 x 32 configuration. On the perimeter of the SDA, a dry drainage channel lies between a dike and fence that surround the disposal area. Rodent populations in this area were studied by placing Longworth live traps at 9 m intervals around the entire perimeter (areas G, H, J, K).

Our study was conducted from May 1978 to July 1979. Perimeter lines and grids were trapped weekly on a staggered basis (i.e., grids on odd weeks, lines on even weeks) from May through October 1978, and monthly thereafter. A trapping session consisted of two days of trapping per grid or line. During this time traps were baited and set in late after-

noon, followed by removal and examination of animals the following morning. Captured animals were eartagged with fingerling fish tags. Data obtained for each captured animal included species, trap location, weight, sex, and reproductive condition.

Three measures of movement (Brant 1962) were used to estimate movements by individual small mammals: (1) D, the average distance between captures from one trapping period to the next, (2) M, the maximum distance between captures from one trapping period to the next, and (3) S, average distance between captures within a two-day trapping session. D and M were employed to estimate how far an animal moved between trapping sessions, whereas S was used to estimate short-term movement, that is, movement from one day to the next within a trapping period. Following individual calculations, data were pooled to estimate average movement values for individual species.

Movement data were first separated into four seasonal periods: winter (December–February), spring (March–May), summer (June–August), and autumn (September–November). These periods corresponded well with changes in temperature and snowfall, as well as changes in population density and re-

TABLE 1. Seasonal estimates of the average distance (m) ($\pm$ S.E. (n = number of animals)) between successive captures from one trapping period to the next (D) and within a trapping period (S) for *Peromyscus maniculatus* in different habitats on and adjacent to the Subsurface Disposal Area. Blanks in the table indicate sample size was less than or equal to five animals.

Habitat	Statistic	Winter	Spring	Summer	Autumn
Crested Wheatgrass	D	28.4 ± 5.2 (11)	25.5 ± 5.2 (46)	27.5 ± 3.8 (104)	23.8 ± 3.1 (83)
(A, B, D)	S	9.0 ± 2.8 (6)	16.2 ± 4.7 (35)	17.8 ± 4.0 (94)	33.7 ± 12.0 (73)
Russian Thistle	D	—	43.2 ± 18.1 (8)	45.1 ± 16.3 (20)	21.1 ± 3.2 (34)
(C)	S	—	—	16.4 ± 2.0 (15)	16.9 ± 4.1 (26)
Sagebrush	D	—	—	43.8 ± 7.0 (8)	—
(M)	S	—	—	19.6 ± 4.1 (6)	—
Fence line	D	21.1 ± 4.9 (50)	34.7 ± 4.7 (149)	36.8 ± 6.1 (195)	24.1 ± 4.5 (212)
(G, H, J, K)	S	14.4 ± 3.3 (33)	26.2 ± 5.3 (122)	20.6 ± 2.9 (165)	14.8 ± 2.4 (162)

TABLE 2. Seasonal estimates of the average distance (m) ($\pm$ S.E. (n = number of animals)) between successive captures from one trapping period to the next (D) and within a trapping peroid (S) for *Dipodomys ordii* and *Microtus montanus* in different habitats on the Subsurface Disposal Area. The blank in the table indicates a sample size was less than five animals.

		Dipodomys ordii	
Habitat	Statistic	Summer	Autumn
Crested Wheatgrass	D	55.3 ± 25.5 (29)	37.5 ± 15.0 (30)
(A, B, D)	S	18.6 ± 3.8 (15)	22.3 ± 6.0 (25)
Fence line	D	51.2 ± 23.6 (38)	29.1 ± 5.1 (90)
(G, H, J, K)	S	33.2 ± 15.5 (30)	21.3 ± 5.9 (74)

		Microtus montanus	
Habitat	Statistic	Spring	Summer
Crested Wheatgrass	D	21.0 ± 3.1 (42)	68.4 ± 22.3 (16)
(A, B, D)	S	14.5 ± 2.9 (20)	33.4 ± 11.2 (8)
Fence line	D	54.0 ± 16.0 (75)	77.2 ± 28.6 (13)
(G, H, J, K)	S	21.2 ± 7.2 (37)	—

production of small mammals on the study area (Groves and Keller 1983a). Next, movement data were tested for differences among habitats within a season. Lastly, data were pooled among habitats to test for differences in movement between sexes and between age classes within a season.

Within any season, an animal was recaptured in no more than six trapping periods; the majority of animals were recaptured four times. Only animals that remained on a grid or trapline during their recapture history were included in the movement analysis, except those animals that moved the short distance between grids and adjacent traplines (see Fig. 1). Movements by small mammals from one trapping line or grid to another within the SDA covered distances of more than 200 m, a length well beyond movements previously reported for any species on our study area (Brant 1962, Ramsey 1969). We considered such movements to be outside the normal home range of an animal and classified such individuals as dispersers. Less than 1% of the small mammals marked on an individual grid or trapline dispersed to another grid or trapline within the SDA. These animals, as well as those small mammals that dispersed off the SDA, will be reported on elsewhere.

Skewness and kurtosis values indicated that the movement data were not normally distributed. Additionally, the assumption of homoscedasticity among groups of movement data within each species was violated. Thus, nonparametric procedures, available as SPSS programs (Nie et al. 1975, Hull and Nie 1979), were employed with $\alpha = 0.05$.

RESULTS

A total of 20,689 live-trap nights produced 9,318 captures of 10 species of small mammals

during the 15-month study (Groves and Keller 1983a). Sufficient data were obtained to estimate average movements for three species: (1) deer mice (*Peromyscus maniculatus*), montane voles (*Microtus montanus*), and (3) Ord's kangaroo rats (*Dipodomys ordii*). Additionally, limited movement data were obtained for Great Basin pocket mice (*Perognathus parvus*).

Kruskal-Wallis (K-W) analyses of variance or Mann-Whitney U tests were used to analyze differences in movement among habitats by *P. maniculatus* in each season (Table 1.). No significant differences in movement (*D*, *S*, or *M*) among habitats were detected for *P. maniculatus*[3]. Subsequently, data from different habitats were pooled to produce a single estimate of movement in each season for *D*, *S*, and *M*.

For *D. ordii* and *M. montanus*, movement data by habitat were only estimated for two seasons because of insufficient sample sizes in other seasons. Mann-Whitney U tests were used to analyze differences in movement between crested wheatgrass and fenceline habitats for both *D. ordii* and *M. montanus* (Table 2). No significant differences in movement between fenceline and crested wheatgrass habitats were detected for *D. ordii* in either summer or autumn by any movement statistic (*D*, *S*, or *M*). In spring, *M. montanus* moved significantly (P ≤ .05) greater distances in fenceline habitat than crested wheatgrass habitat as indicated by *D* and *M*. No significant differences in movement between habitats were found for *M. montanus* in summer. Subsequently, data from different habitats were pooled for both *D. ordii* and *M. montanus* to produce a single estimate of movement in each season for *D*, *S*, and *M*.

A K-W analysis of variance followed by multiple range tests indicated that *P. maniculatus* moved longer distances in spring and summer than other seasons, as estimated by *D* or *M* (P ≤ .05, Fig. 2a). Seasonal estimates of *D* ranged from approximately 22 m in autumn and winter to 32 m in spring and summer. Estimates of *D* and *M* were significantly different (P ≤ .05) among spring, summer, and autumn periods for *D. ordii* (Fig. 2b). There
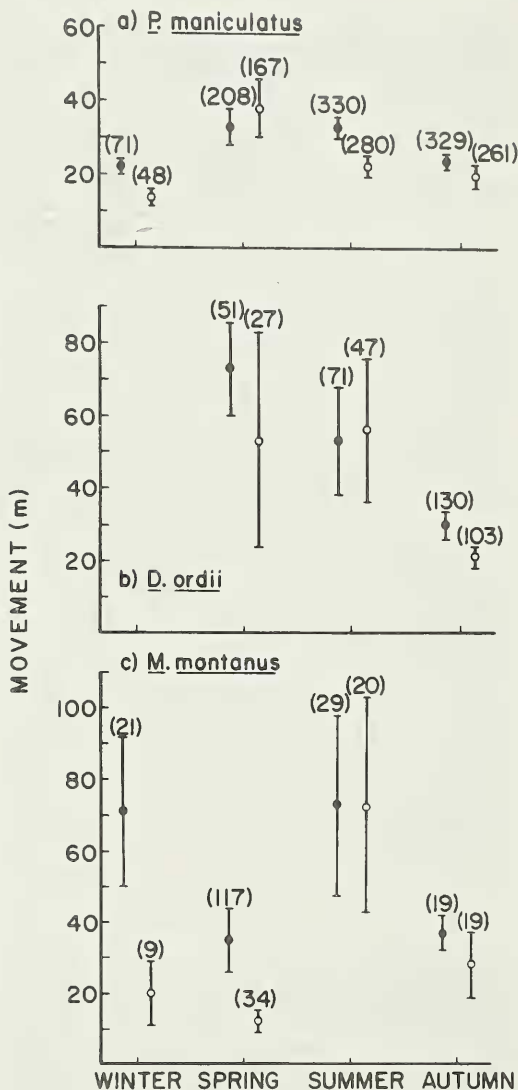

Fig. 2. Seasonal estimates of *D* and *S* for *P. maniculatus* (a), *D. ordii* (b), and *M. montanus* (c) on and adjacent to the Subsurface Disposal Area. Closed circles = *D*; open circles = *S*; bars = S.E.; sample sizes are in parentheses.

was a trend of decreasing range of movement from spring to autumn, with *D* ranging from approximately 72 to 35 m in these periods. Because only a few *D. ordii* were captured in winter (Groves and Keller 1983a), movements could not be estimated for this season. Both *D* and *M* were significantly greater (P ≤ .01) in winter and summer compared to spring and autumn for *M. montanus* (Fig. 2c). Estimates of *D* ranged from approximately 70 m in winter and summer to 37 m in spring and autumn.

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[3]Because estimates, errors, and sample sizes for *M* were similar to *D* for all species, these data were excluded from the text but are available from the authors.

TABLE 3. Estimates of movement (m) (± S. E. (n = number of animals) for male and female *Microtus montanus* and *Dipodomys ordii* on and adjacent to the Subsurface Disposal Area. All pairs of male and female movements shown in the table were significantly different (P < .05).

Species	Season	Statistic	Male	Female
M. montanus	Spring	D	36.6 ± 6.0 (40)	26.6 ± 10.2 (56)
	Autumn	S	41.4 ± 16.7 (8)	6.0 ± 2.1 (11)
D. ordii	Spring	D	44.2 ± 6.0 (31)	21.5 ± 4.2 (20)
	Summer	D	37.8 ± 5.0 (36)	43.2 ± 22.4 (35)

Short-term movements (*S*) were not significantly different among seasons for any species, but they were generally less than *D* for all species.

A series of Mann-Whitney U tests was used to detect differences in movement (*D* and *S*) between males and females within each season. No significant differences in movement were found between male and female *P. maniculatus* in any season. In spring male *M. montanus* and male *D. ordii* moved greater distances than females, as indicated by *D* (Table 3). In fall male *M. montanus* moved greater distances within trapping sessions (*S*) than females (41 m vs. 6 m), although sample sizes were small for this comparison. Lastly, female *D. ordii* moved greater distances than males in summer.

Mann-Whitney U tests were also used to detect differences in movement (*D* and *S*) between age classes for *P. maniculatus* and *M. montanus*. The mean weight at sexual maturity was used to separate juveniles from adults (Groves 1981). No distinctions were made between juvenile and adult *D. ordii* because of difficulties in assessing external sexual characteristics. No significant differences in movement between age classes of *P. maniculatus* were observed in any season. For *M. montanus*, juveniles moved significantly greater (P ≤ .05) distances between trapping sessions (*D*) than adults in spring (55.2 ± 20.2 m (n = 10) vs. 15.6 ± 2.5 m (n = 36)). Additionally, juvenile *M. montanus* moved greater (P ≤ .05) distances within a trapping session (*S*) than adults (53.8 ± 29.6 m (n = 4) vs. 14.8 ± 9.9 m (n = 8)), although sample sizes were small for comparative purposes.

Although sufficient sample sizes were not available to estimate seasonal movements by *P. parvus*, *D* and *M* were estimated by pooling data from spring and summer. The majority of these values were determined from recapture records on Grids A and B in crested wheatgrass stands and Grid M in sagebrush habitat. Average distance between successive captures (*D*) ± S.E. for *P. parvus* was 45.0 ± 15.8 m (n = 14); maximum distance between successive captures (*M*) was 60.8 ± 26.3 m (n = 14).

DISCUSSION

Local movements by small mammals have received considerable attention in the ecological literature. Most studies published to date have concentrated on home ranges (expressed in areal terms) of individual species as determined by live trapping on grids for short periods of time. Because our primary objective was to determine the distance that a small mammal could transport contaminated material, we abandoned the concept of home range in favor of data on the magnitude of average linear movements by small mammals occupying the Subsurface Disposal Area.

On the SDA, *P. maniculatus* showed significantly reduced movements in autumn and winter compared to spring and summer. Colder temperatures and a concomitant reduction in activity may have been responsible for the lesser movements in these seasons. Stebbins (1971) has documented periods of torpor for *P. maniculatus* in Canada during periods of snow and cold. Similarly, *D. ordii* moved significantly lesser distances in autumn compared to spring and summer. This observation, coupled with the fact that we captured few *D. ordii* in winter (Groves and Keller 1983a), suggests that cold weather may also affect activity in this species. O'Farrell (1974) previously reported that *D. ordii* may enter periods of torpor during cold weather.

No significant differences were found between movements of male and female *P. maniculatus* on the SDA, although adults did move greater lengths than juveniles in summer. Both of these results are in agreement

with the findings of Brant (1962). Stickel (1968) noted that immature *Peromyscus* remain near the natal site until the dispersal period that coincides with sexual maturity. Consequently juvenile *P. maniculatus* on the SDA could be expected to show reduced linear movements when compared to adults. In spring juvenile *M. montanus* moved significantly greater distances than adults. These longer movements may have resulted from juveniles dispersing from an increasing *M. montanus* population (Groves and Keller 1983a), a phenomenon reported by several authors for microtine populations (Myers and Krebs 1971).

No data on movements have been published for *P. parvus*. Our data indicated that this species moved approximately 45 m between successive captures (D) in crested wheatgrass habitat during spring and summer. Thus, *P. parvus* exhibited linear movements slightly less than *D. ordii*, a larger rodent in the same family (Heteromyidae).

In addition to the grids and traplines located on the SDA for assessing rodent populations there, dispersal from the area was estimated with subsampling systems used to enumerate the fraction of the populations that permanently leave the SDA. Although a variety of factors affect the degree of accuracy of such estimates (Keller 1978), our data suggest that only 22% of the small mammals occupying the SDA dispersed on an annual basis. Thus, the majority of movements by small mammals occupying the disposal area were found to occur within its boundaries. An obvious corollary is that the majority of contaminated small mammals also remain within the SDA during their movements.

Data from the radioecology aspects of our study indicated that some *P. maniculatus* and *D. ordii* on the SDA received radiation doses significantly higher than animals from control areas (Arthur et al. 1986). In addition, concentrations of several radionuclides in *P. maniculatus* tissues from the SDA were significantly higher than those from control areas (Arthur et al. in press a). Coyote fecal samples collected adjacent to the SDA boundary contained elevated concentrations of one radionuclide, presumably from uptake of contaminated small mammals (Arthur and Markham 1982). Because average linear movements by small mammals on the SDA range from 20 to 70 m, it is likely that most of the primary redistribution of contaminated material by small mammals via predation occurs within this range from the point of contamination on the SDA. This type of information should be helpful to waste management personnel in implementing a biotic monitoring plan.

The environmental consequences of radiation doses and radionuclide uptake by small mammals on the SDA are likely minimal because the overall amount of radioactivity transported by small mammals off the SDA is small (Arthur et al. in press, 1986) and no adverse impacts to small mammals on the SDA have been observed. Beyond the practical application of these movement data, this study has also provided new information on linear movements by small mammals in crested wheatgrass, Russian thistle, and sagebrush habitats, all common in the Great Basin. Prior to this study, no information was available on movements by *P. parvus*; data on linear movements by *P. maniculatus*, *D. ordii*, and *M. montanus* were not previously reported for any of the above habitats. Therefore, our movement data contribute new information to the natural history of these four small mammal occupants of the Great Basin.

ACKNOWLEDGMENTS

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